



**United Nations Environment Programme**  
**WMO/UNEP Ozone Research Managers**  
**12<sup>th</sup> ORM Meeting, 24-26 April 2024 Genève**



**Benefits of the Montreal Protocol:  
effects on climate, UV radiation and  
stratospheric ozone**

**Janet F. Bornman**  
**Co-Chair**  
**Environmental Effects Assessment Panel**  
**(EEAP)**



# Benefits of the Montreal Protocol



Life on Earth





# Environmental Effects Assessment Panel

## Quadrennial Assessment 2022



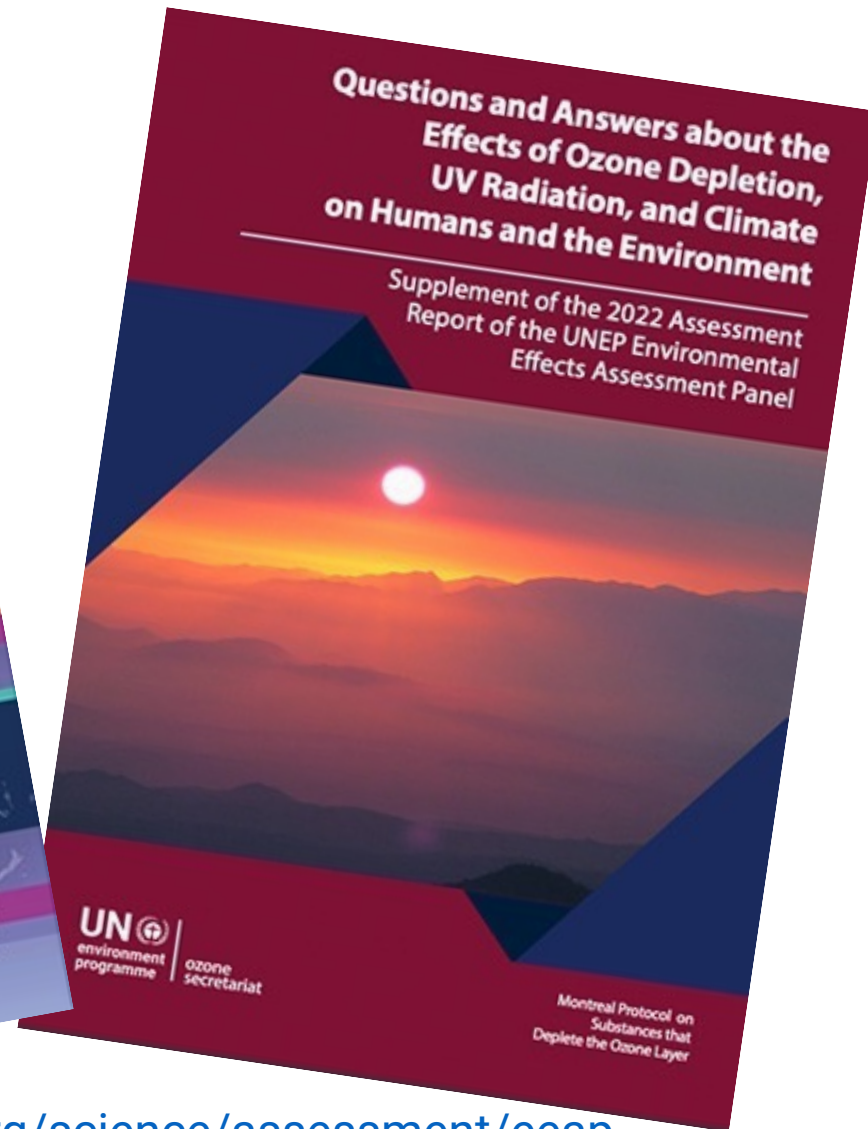
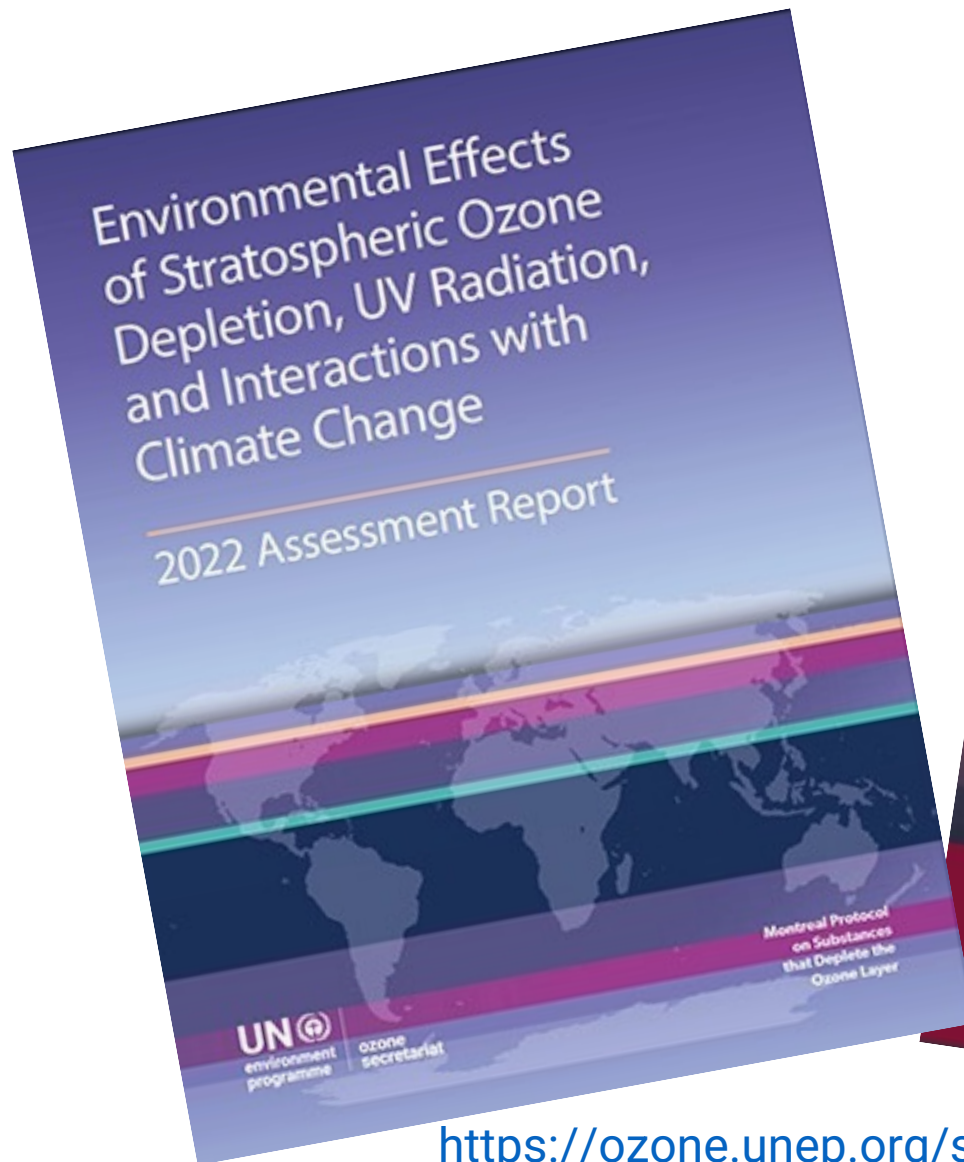
### 7 interconnecting chapters on the following topics

	<b>Interactive effects of stratospheric ozone &amp; climate change on:</b>
1	Solar ultraviolet radiation
2	Human health
3	Terrestrial ecosystems & Biogeochemical cycles
4	Aquatic ecosystems
<b>5</b>	Microplastics in the environment
6	Composition of the troposphere and air quality
7	Natural and synthetic materials



# Environmental Effects Assessment Panel

## Quadrennial Assessment 2022



<https://ozone.unep.org/science/assessment/eeap>



**The Montreal Protocol** contributions to the UN SDGs originate from protection of the stratospheric ozone layer and the mitigation of climate change (ODS; Kigali Amendment)





**The Montreal Protocol** contributions to the UN SDGs originate from protection of the stratospheric ozone layer and the mitigation of climate change (ODS; Kigali Amendment)



**EEAP focus on SDGs includes:**

**human health**

**food security**

**contaminants & pollution**

**biodiversity**

**air & water quality**

**terrestrial & aquatic ecosystems**

**sustainable production & consumption**

**climate change**

**SUSTAINABLE DEVELOPMENT GOALS**



# Benefits of the Montreal Protocol



**UV irradiation – a significant risk factor and beneficial**

**Sunburn**

**Inflammatory  
skin disorders**

**Skin  
cancer**

**Systemic immuno-  
suppression**

**Skin ageing**

**Eye disorders**

**Photochemical smog**

**Production of  
vitamin D**

**Reduced certain  
autoimmune  
disease**

**Reduced  
infection**

**Reduced  
myopia**

**Decreased  
risk of some  
metabolic  
disorders**

**May reduce  
cancer mortality**

**May lower  
blood pressure**

**May reduce  
cardio-  
vascular  
disease**

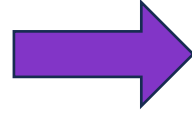
**Cleans the atmosphere ( $\cdot\text{OH}$ )**



# Benefits of the Montreal Protocol



High values of UV Index still occur



Highest UV Index recorded: 25.8

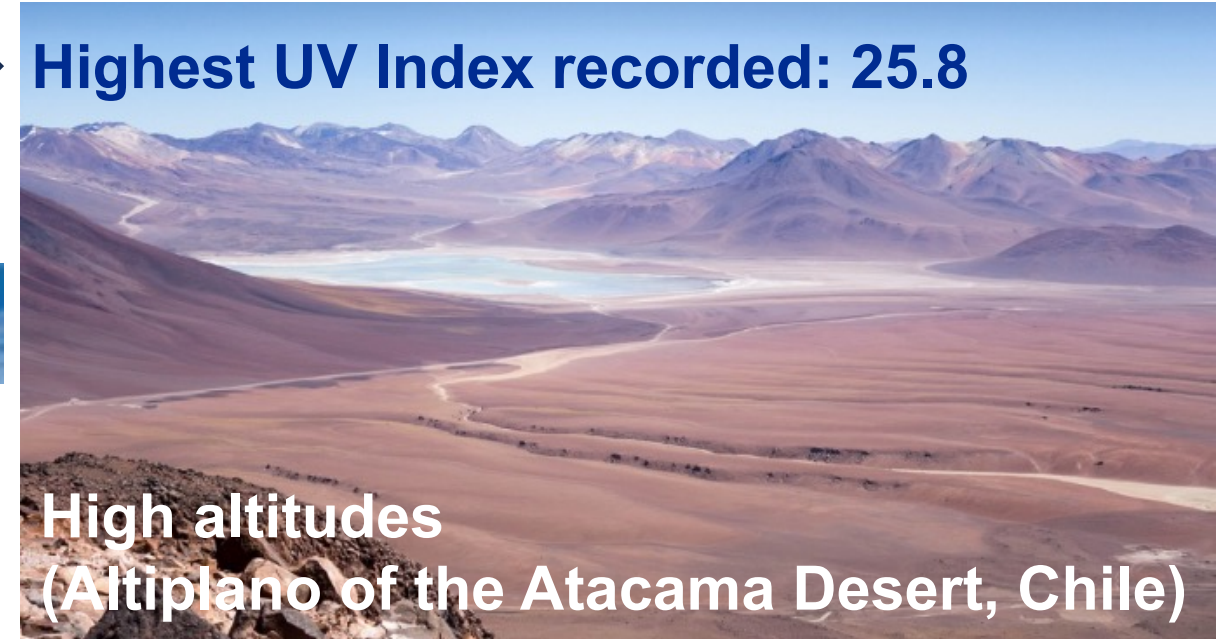
Measurements from satellites  
During cloud enhancement



reflected radiation



UVI increased by *ca* 30% above UVI 20  
expected for clear skies



High altitudes  
(Altiplano of the Atacama Desert, Chile)

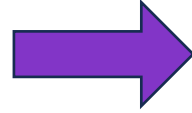




# Benefits of the Montreal Protocol



High values of UV Index still occur



Highest UV Index recorded: 25.8

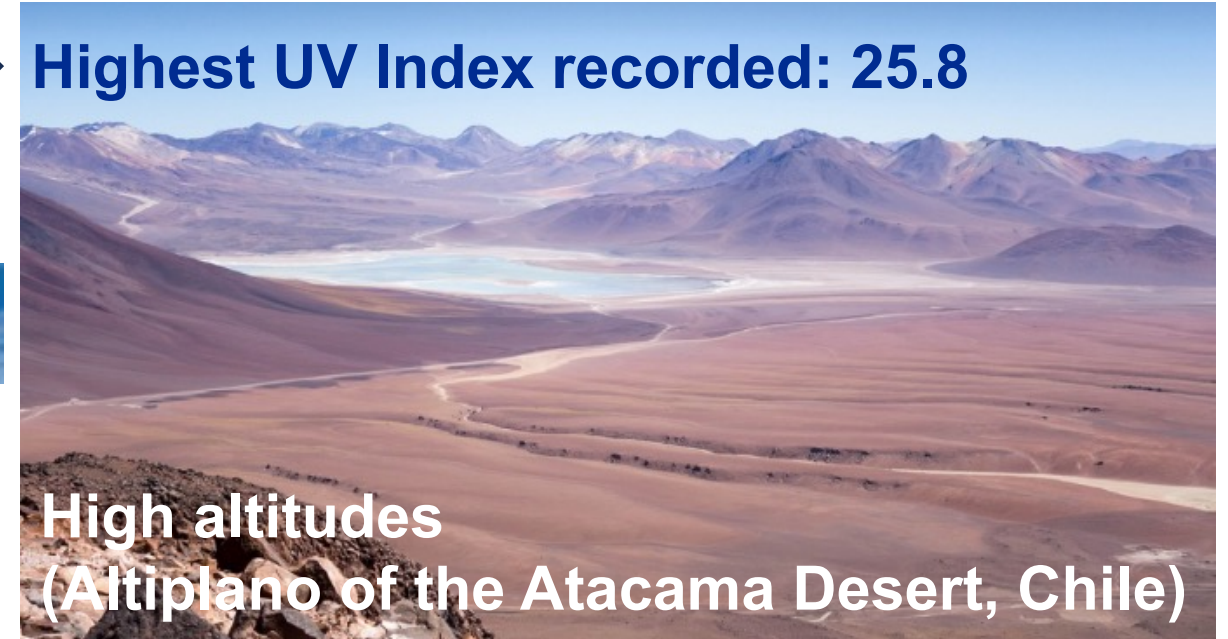
Measurements from satellites  
During cloud enhancement



reflected radiation



UVI increased by ca 30% above UVI 20  
expected for clear skies



High altitudes  
(Altiplano of the Atacama Desert, Chile)

**Without the Montreal Protocol**

Clear-sky UV Index using model calculations, noon, summer, tropical mid-latitudes:

UVI of 40 by end of the 21<sup>st</sup> century (McKenzie et al. 2019)



## Benefits of the Montreal Protocol



Examples of environmental consequences of changes in ozone, UV radiation and climate

**An extreme UV-B radiation scenario estimated the impact on terrestrial vegetation without the Montreal Protocol\***



**Drastic reduction of photosynthetic uptake & storage of carbon dioxide by plants**



**increased atmospheric carbon dioxide levels with additional rise of global mean surface temperature of 0.5-1.0 °C by 2100**

\*Young, P.J., et al. 2021. *Nature* **596**, 384–388



## Benefits of the Montreal Protocol

Examples of environmental consequences of changes in ozone, UV radiation and climate

An extreme UV-B radiation scenario estimated the impact on terrestrial vegetation without the Montreal Protocol\*



Drastic reduction of photosynthetic uptake & storage of carbon dioxide by plants



increased atmospheric carbon dioxide levels with additional rise of global mean surface temperature of 0.5-1.0 °C by 2100

Effects of UV radiation and climate change on biodiversity

Reduced geographical range/availability of suitable habitats for plants and animals → species extinction, ecosystem disruption

\*Young, P.J., et al. 2021. *Nature* 596, 384–388



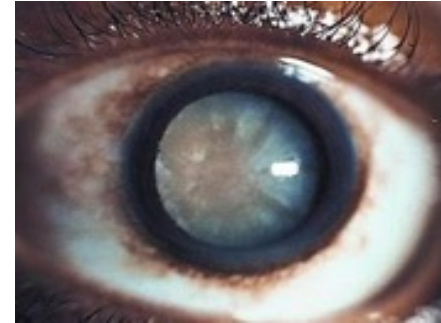
# Benefits of the Montreal Protocol



## Avoidance of increased critical health conditions

### Challenges for balancing harms and benefits of sun exposure

UV-B (280-315 nm) wavelengths that produce beneficial vitamin D are the same as those most harmful to skin and eyes



### KEY MESSAGE

Due to protection of the ozone layer, the Montreal Protocol has prevented large increases in UV radiation that **would have made it more difficult to achieve this balance**



## Benefits of the Montreal Protocol



### Avoidance of increased critical health conditions

#### **Skin cancer**

**UV radiation** - main cause of skin cancer

Can also lead to inflammatory skin conditions

*Can be difficult to separate effects of changes in ozone and sun exposure behaviour*



# Benefits of the Montreal Protocol



## Avoidance of increased critical health conditions

### **Skin cancer**

**UV radiation** - main cause of skin cancer

Can also lead to inflammatory skin conditions

*Can be difficult to separate effects of changes in ozone and sun exposure behaviour*

Increasing incidence in **invasive melanoma in high-risk populations**

Canada, The Netherlands, Lithuania, parts of United States & Australia

Increases also in some **lower-risk countries** (with darker skin types)

Columbia, Brazil, Jordan, & South Korea



# Benefits of the Montreal Protocol



## Avoidance of increased critical health conditions

### Skin cancer

**UV radiation** - main cause of skin cancer

Can also lead to inflammatory skin conditions

*Can be difficult to separate effects of changes in ozone and sun exposure behaviour*

Increasing incidence in **invasive melanoma in high-risk populations**

Canada, The Netherlands, Lithuania, parts of United States & Australia

Increases also in some **lower-risk countries** (with darker skin types)

Columbia, Brazil, Jordan, & South Korea

Increasing incidence of **keratinocyte cancers**

(squamous cutaneous carcinoma & basal cell carcinoma)

Without the Montreal Protocol, highly likely larger increases would have occurred



# Benefits of the Montreal Protocol

## Avoidance of increased critical health conditions



### Medications sensitive to UV radiation (photosensitisers)



can lead to inflammatory skin conditions  
In spring or summer under high UV radiation



may cause skin cancer  
possibly due to damaged and  
non-repaired DNA



Example: polymorphic  
light eruption on skin

An important area of emerging research because of the high use of some of the photosensitising drugs





# Benefits of the Montreal Protocol



## Eyes and UV radiation

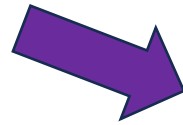
Most of the harmful UV radiation is absorbed as it penetrates cornea & lens



Therefore mostly the anterior, surface area can be damaged



Pterygium, photokeratitis, cataract, & cancers of the ocular surface



Eyelid

Pupil

Sclera

Iris

Ciliary

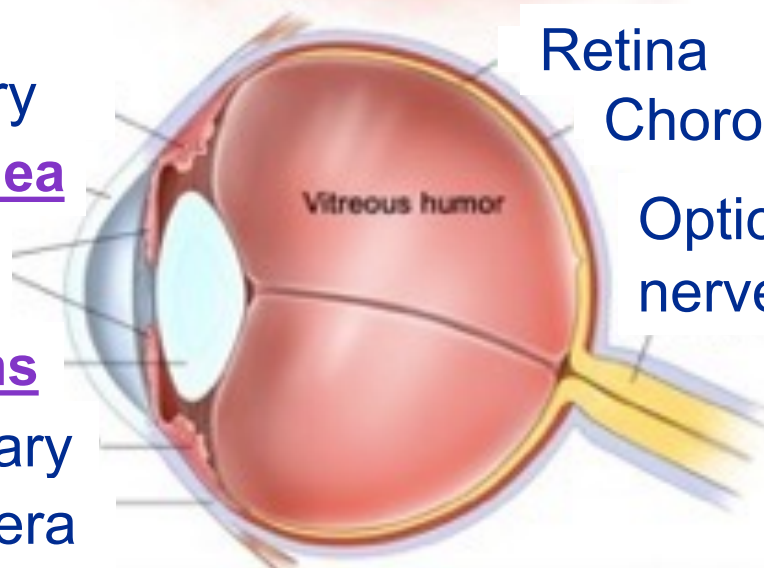
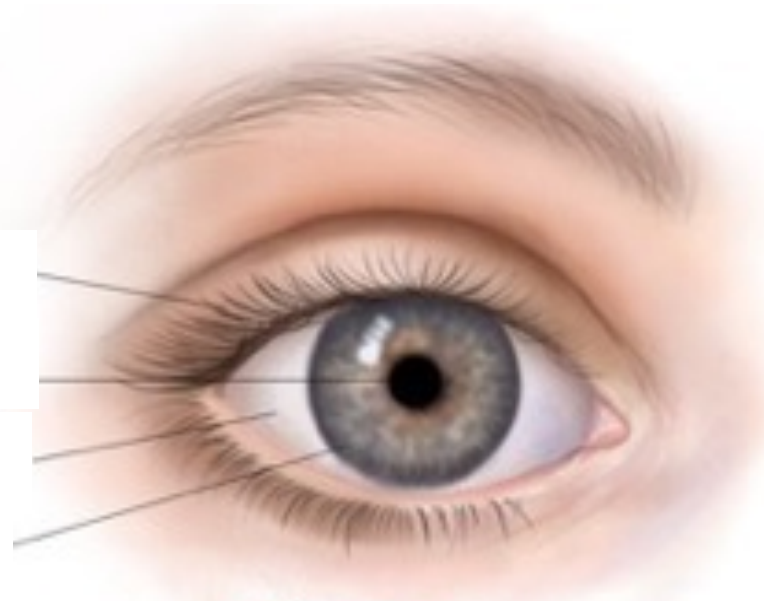
Cornea

Iris

Lens

Ciliary

Sclera



**The Montreal Protocol has prevented millions of certain eye diseases by UV radiation**

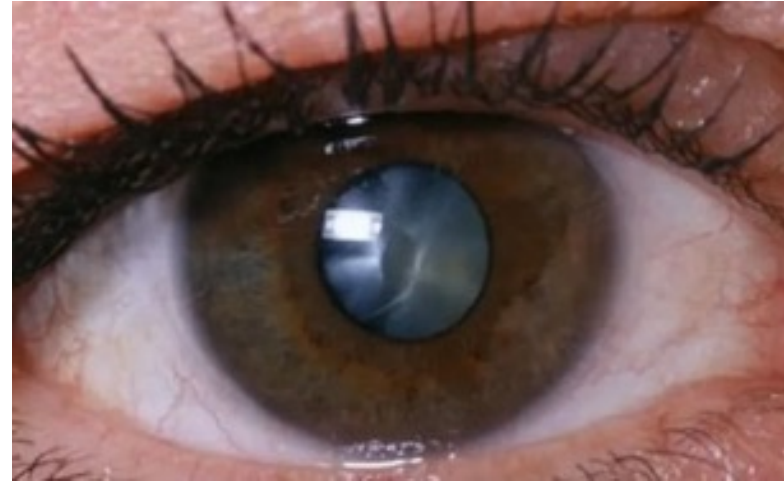
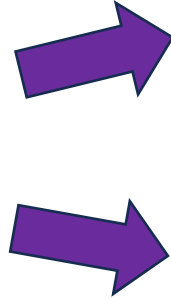


# Benefits of the Montreal Protocol

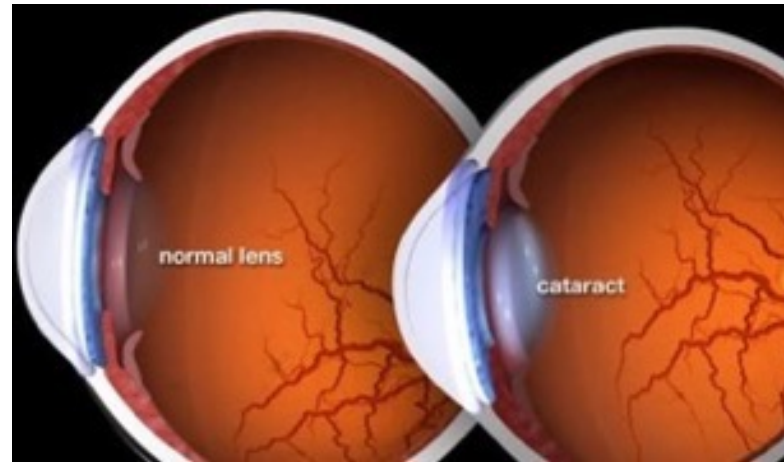


**Eyes and UV radiation**

**Pterygium, photokeratitis, cataract**



**Pterygium**



**Normal**

**Cataract**

**The Montreal Protocol has prevented millions of certain eye diseases by UV radiation**



# Benefits of the Montreal Protocol



**Estimations of a modelling study for people born in the United States**  
(data are being updated)

**The Montreal Protocol - skin cancers & cataracts avoided:**

**11 million cases of melanoma**

**432 million cases of basal cell and squamous cell carcinoma**

**63 million cases of cataracts**

**Cataracts are still a major cause of impaired vision & blindness**

**Chinese adults aged 65 years & older (in suburban Shanghai)**

**Average incidence: 57%\***

\*Zhang, S., et al. (2023). *British Journal of Ophthalmology*, 107(5), 683-689



# Emerging and growing issues of concern



## 21st century outlook

### Factors that may affect stratospheric ozone and ground-level UV radiation

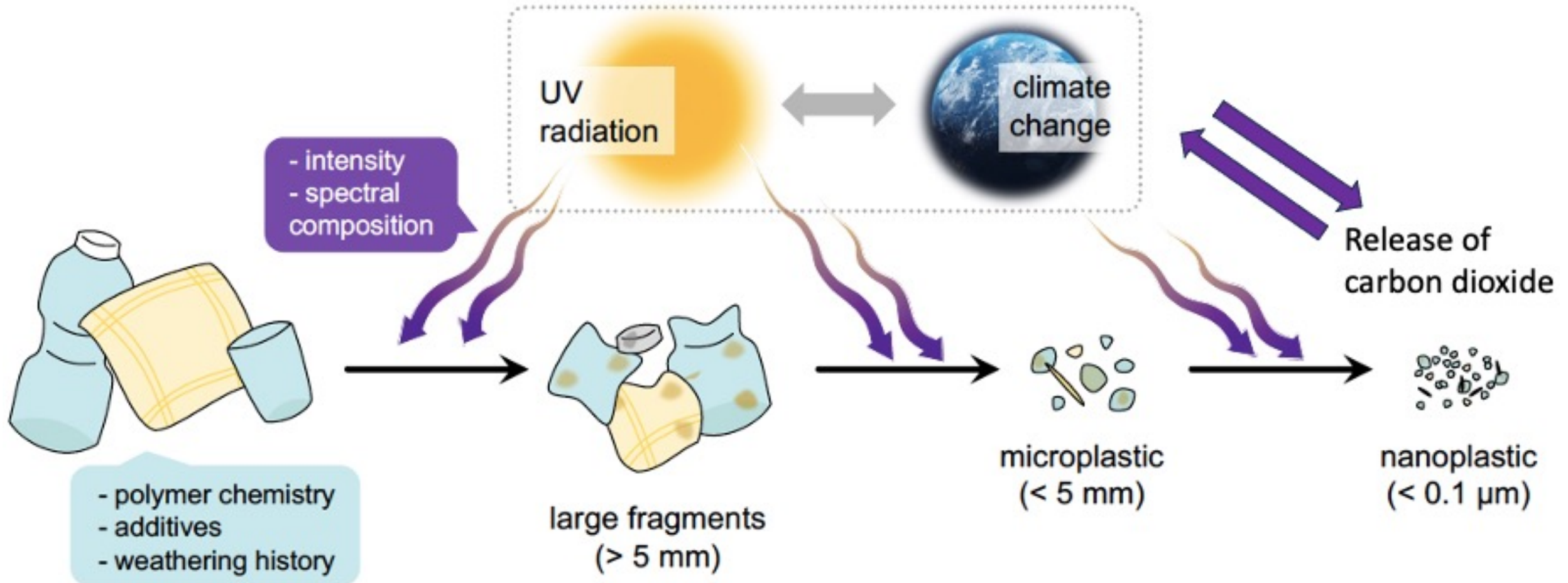
- **Continuing greenhouse gas concentrations**
- **Ozone-depleting halogen-containing chemicals (lifetime < 6 months, VSLs)**
- **Climate change effects on cloud cover, aerosols, atmospheric circulation, and surface reflectivity**
- **Air pollution and tropospheric aerosols**
- **Wildfires**
- **Supersonic aircraft**
- **Potential nuclear war**
- **Potential future climate intervention (solar radiation modifications)**
- **Volcanic eruptions**
- **Plastic pollution and the role of UV radiation**



# Emerging and growing issues, and the role of UV radiation



## UV radiation and climate change: main drivers of plastic breakdown





# Emerging and growing issues, and the role of UV radiation



## UV radiation and climate change: main drivers of plastic breakdown

**2021:** World annual plastic production estimated at 391 million metric tonnes



ca 40% ends up in the environment as plastic waste

**Since 1950's:** 8,300 million metric tons of plastics produced



ca 80% now in landfills & the natural environment



The Intergovernmental Negotiating Committee (INC) is developing an international legally binding agreement to end plastic pollution



# Emerging and growing issues, and the role of UV radiation



## UV radiation and climate change: main drivers of plastic breakdown

### Plastic waste exposed to solar UV radiation

- photo-oxidises 
- degrades into microplastic (<5 mm) & nanoplastic (<0.1 μm) particles
- releases toxic by-products



- ❑ Transferred along the food chain to consumers
- ❑ Found in drinking water, foods, human organs, blood, etc
- ❑ Biological effects are under investigation



## Benefits of the Montreal Protocol



**UV radiation and climate change: main drivers of ageing of plastic and wood**

**□ Innovation stimulated by the focus of UV radiation on materials**

**Plastic & wood industries use additives to slow down ageing processes**

**However, some of these additives are endocrine disruptors or potential carcinogens**



**released into the environment & food chains**





# Benefits of the Montreal Protocol



**UV radiation and climate change: main drivers of ageing of plastic and wood**

□ **Innovation stimulated by the focus of UV radiation on materials**

**Plastic & wood industries use additives to slow down ageing processes**

**However, some of these additives are endocrine disruptors or potential carcinogens**



**released into the environment & food chains**

---

□ **Replacement of legacy chemicals for blocking transmittance of UV radiation**

Examples:

**Instead of traditional glass with UV blockers - transparent wood composite material**

**Decreasing or preventing UV transmission in modified fabrics**



**Nanocomposites (zinc oxide (ZnO) & polyurethane) also provided antimicrobial or insect repellent properties**

# UV reflection, transmission and absorption for UV-protective fabrics



But may lead to increasing release of metal particles into the environment



# Benefits of the Montreal Protocol



**UV irradiation –a significant risk factor and beneficial**

Sunburn

Inflammatory skin disorders

Skin cancer

Systemic immunosuppression

Skin ageing

Eye disorders

Photochemical smog

**Benefits of exposure to moderate UV radiation possible because of the Montreal Protocol**

**Production of vitamin D**

**Reduced certain autoimmune disease**

**Reduced infection**

**Reduced myopia**

**Decreased risk of metabolic disorders**

**May reduce cancer mortality**

**May lower blood pressure**

**May reduce cardiovascular disease**

**Cleans the atmosphere ( $\cdot\text{OH}$ )**

